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An Economic Evaluation of a Process To Separate Raw Urban Refuse Into Its Metal, Mineral, and Energy

UNITED STATES DEPARTMENT OF THE INTERIOR

U.S. Bureau of mines.

Information Circular 8732

An Economic Evaluation of a Process To Separate Raw Urban Refuse Into Its Metal, Mineral, and Energy Components

By Thomas A. Phillips

March 3, 1849

UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary

BUREAU OF MINES

AB

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

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PREFACE

This publication is one of a series of economic evaluations on mineral- and mining-related processes published by the Bureau of Mines.

The intent of an economic evaluation is to present a capital and operating cost estimate of a commercial-size plant. Such estimates may be used as an aid for studies and decisions, after being tailored to the special needs of a particular location and being brought to a common time basis.

In the preparation of any economic evaluation, it is necessary to make many assumptions about the process, how it is operated, its location, etc., to produce a meaningful result. In general, if an assumption can be made that applies to the majority of the potential plants, and/or has only a small effect on process capital or operating costs, and/or can be modified easily by a user of the economic evaluation report, then the assumption is made and documented. An example of such an assumption in this report is that the refuse receiving and primary bulk separation portions of the plant operate two shifts per day, 6 days per week.

However, if an assumption is necessary which may not apply to a majority of plants, and/or may have a major effect on capital or operating costs, then that item is generally excluded from the evaluation and the exclusion documented. An example of such an exclusion in this report is that land cost has been excluded from the evaluation.

Because of the large number of assumptions necessarily present in any of its economic evaluations, the Bureau strives to present its evaluations in a format sufficiently detailed and flexible to allow for the inevitable changes and adjustments a user must make to reflect his particular situation. Comments about the utility of both the content and format of this and other information circulars are welcomed by the Bureau.

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AN ECONOMIC EVALUATION OF A PROCESS TO SEPARATE RAW URBAN REFUSE INTO ITS METAL, MINERAL, AND ENERGY COMPONENTS

by

Thomas A. Phillips[1]

ABSTRACT

An economic evaluation of the Bureau of Mines process for the separation of raw urban refuse into its metal, mineral, and energy components is presented. The process recovers ferrous metal, mixed nonferrous metals, aluminum, mixed-color glass cullet, and refuse-derived fuel products from raw refuse. Data for this evaluation were obtained from selected runs at the Bureau's pilot plant in Edmonston, Md.

A cost estimate was prepared for a plant capable of processing 1,000 tons per day of raw urban refuse operating two shifts, 6 days per week. The fixed capital cost, based on second quarter 1976 equipment costs, is approximately $14.5 million excluding land and shipping containers. The estimated operating cost is approximately $8 per ton of refuse processed. This does not include credit for the products, transportation of the products, a tipping fee, or a dumping fee for wastes produced. No finance charges or taxes are included in the operating costs.

INTRODUCTION

Each year the United States generates about 130 million tons of municipal and commercial refuse (4).[2] This refuse contains significant quantities of metals and minerals, which could be recycled. In addition, the bulk of the refuse is composed of paper, plastic, and other combustibles, which represent a potential source of energy. Recovery of these resources would help alleviate a serious solid waste disposal problem as well as conserve our own dwindling natural resources.

The Bureau of Mines, in its research on methods of handling solid wastes, has developed a process for separating raw refuse into its component parts. This process has been successfully demonstrated by a pilot plant, shown in figure 1, which began operation in 1973. The pilot plant, described in detail in two publications (6-7), is designed to process 5 tons per hour of raw

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[1] Chemical engineer, College Park Metallurgy Research Center, College Park, Md.

[2] Underlined numbers in parentheses refer to items in the list of references preceding the appendix.

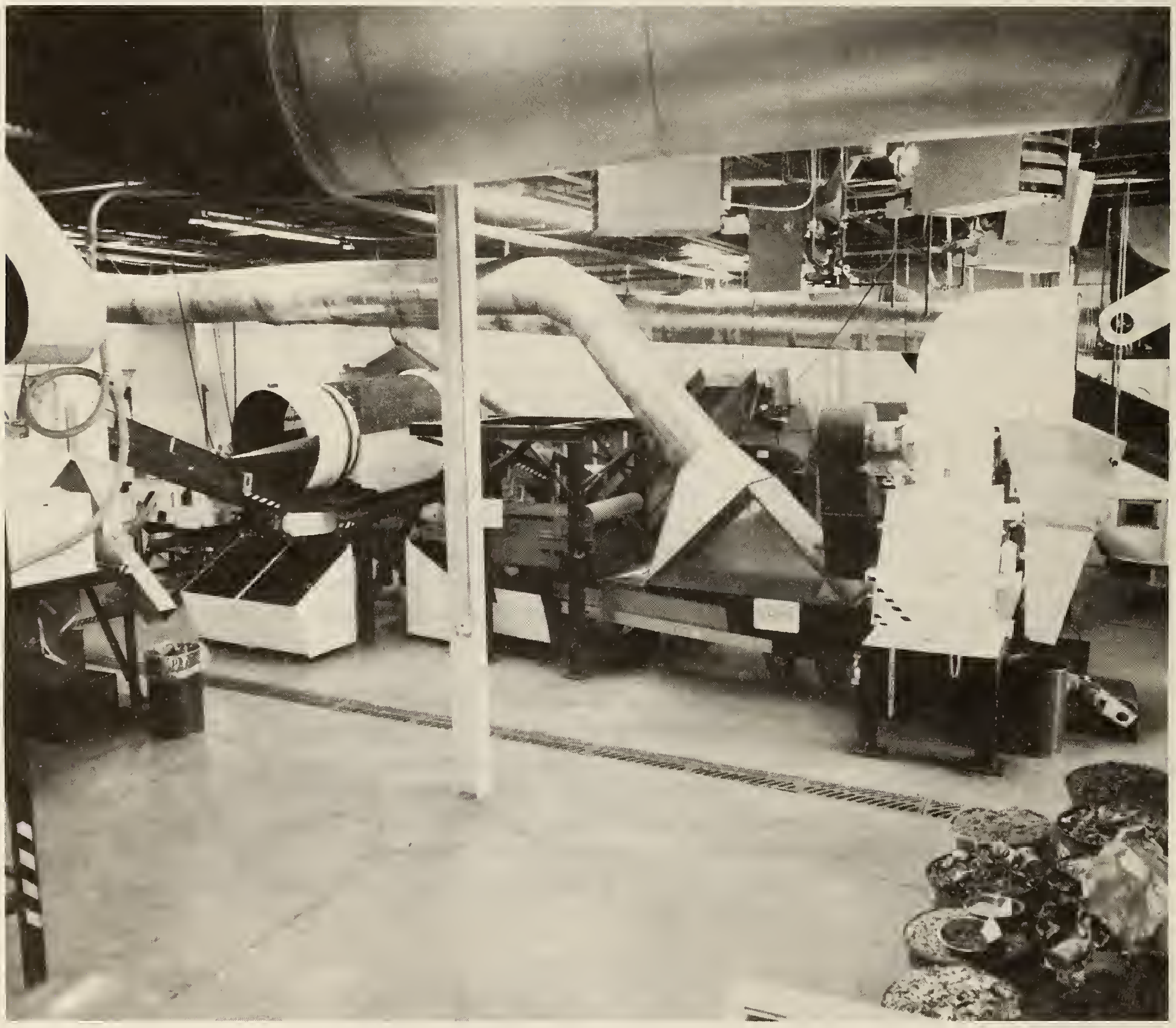

FIGURE 1. - Raw refuse separation pilot plant.

refuse. Scrap iron, nonferrous metals, glass, and RDF (refuse-derived fuel) are mechanically separated and recovered.

Separation and recovery of resources from solid waste already exists on a large scale. Magnetic recovery of ferrous metal is well established and proven at many landfills and incinerators across the country. The city of Ames, Iowa, is currently operating a 200-ton-per-day solid waste separation plant which was formally dedicated on July 16, 1973 (3). The plant is designed to produce fuel for a municipal powerplant and to recover ferrous metal, aluminum, and glass from the refuse. Additionally, a larger 2,000-ton-per-day separation plant is now being designed for Monroe County, N.Y. The plant will be based in part on the Bureau-developed process.

This report is an economic evaluation of a proposed commercial-size plant to separate raw refuse into various fractions based on the Bureau's process. Data for this evaluation are based on results from actual pilot plant runs using refuse samples collected both from a variety of locations and during different seasons. The results are therefore not peculiar to any one location or one specific time of the year.

PROCESS DESCRIPTION

The separation process is designed to recover ferrous metal, mixed nonferrous metal, aluminum, glass, and RDF from raw urban refuse. While not totally eliminating the need for a landfill, this process will greatly reduce the quantity and volume of material to be disposed of. It is assumed that the refuse to be processed will be raw urban refuse collected from a city or town and including some commercial trash. Industrial, oversize bulky waste, or other specialized refuse will not be handled.

A plant is designed to process an average of 1,000 tons per day of raw urban refuse. Twenty-five percent extra capacity is included in the design to handle anticipated surges, such as could be expected after a holiday when the plant was closed and refuse was not collected. The plant operates two shifts, 6 days per week with regular maintenance scheduled for the third shift. The flow diagram for the plant is shown in figure 2. Table 1 shows the estimated quantities of various fractions recovered. These numbers are based on average data collected at the pilot plant from a number of refuse samples.

TABLE 1. - Average quantity of products recovered from 1,000 tons of raw urban refuse

Products	Tons
Refuse-derived fuel (RDF)	668
Heavy organic fuel	139
Light-gage iron	56
Mixed-color glass cullet	76
Nonferrous metal (aluminum)	4.4
Mixed heavy nonferrous metals	1
Massive iron	11
Massive nonferrous metals	3
Landfill	56
Total	[1]1,014.4

[1] Extra weight due to water added during glass recovery.

The plant is designed to include the following items:

1. Temporary storage of 1,000 tons of refuse.

2. Complete recovery of all solids entering the plant with all valuable components in recyclable form.

3. Waste water treatment equipment to remove solids.

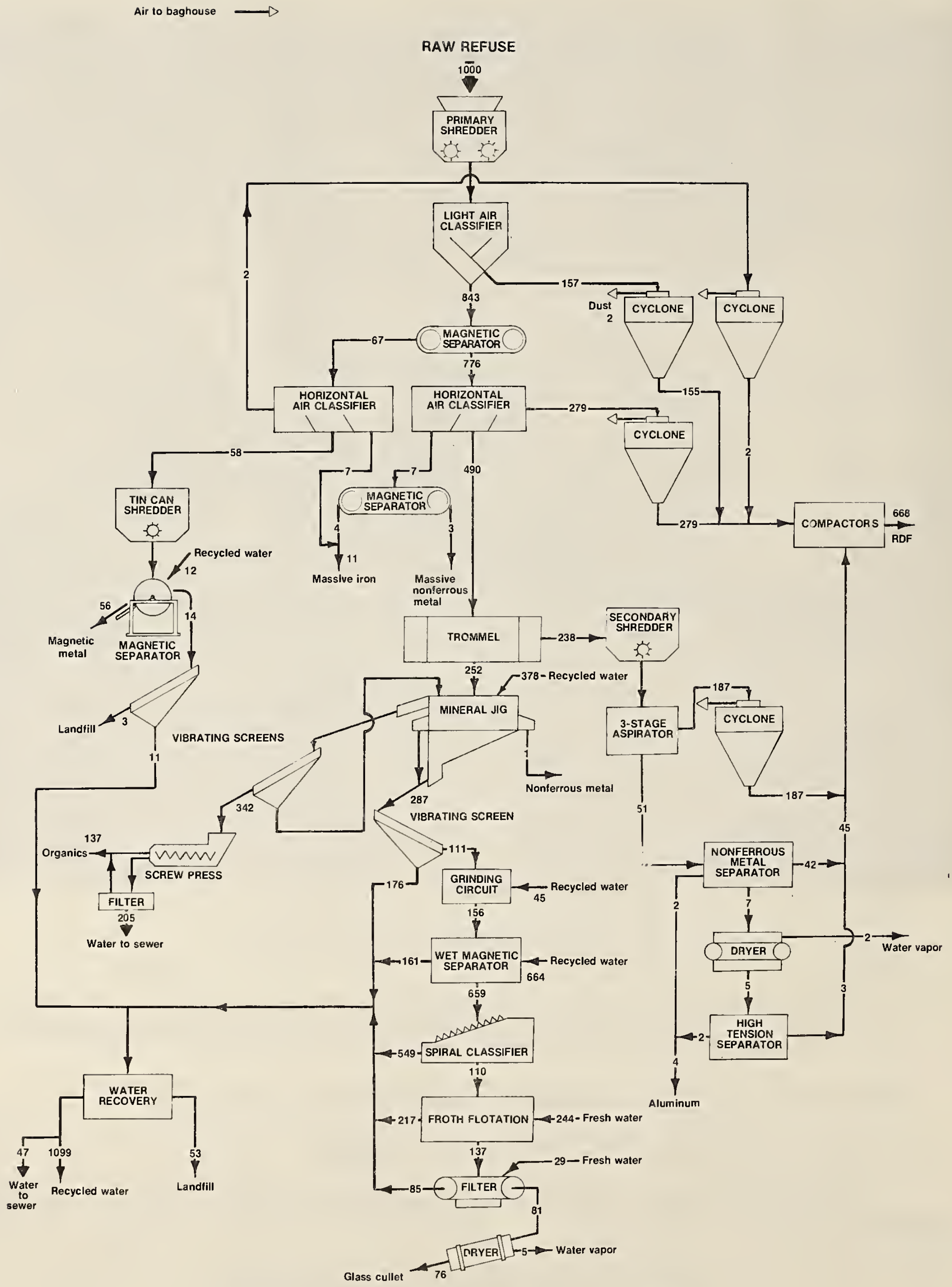

FIGURE 2. - Raw refuse separation process.

Not included in the plant design are:

1. Plant location.
2. Onsite storage of products.
3. Transportation of products.

To simplify the process description, the plant has been divided into seven sections; refuse receiving, primary bulk separation, glass recovery, ferrous metal cleaning, RDF handling, nonferrous metal recovery, and water recovery.

Refuse Receiving

Raw urban refuse is delivered to the plant by standard refuse collection vehicles. Because these trucks will arrive at random intervals, concentrated during a few short periods, the receiving section has been designed to handle up to 50 trucks per hour.

Upon arrival at the plant, the trucks are weighed on scales and then assigned a slot on the tipping floor from which they will discharge their contents. Unloaded trucks are reweighed before leaving the facility. An extra weight scale is provided to prevent delay should one scale fail. It is estimated that the maximum tipping time will not exceed 12 minutes; therefore, 10 tipping slots are provided to accommodate 50 trucks per hour.

Refuse is dumped from the tipping floor directly into a receiving pit. On the floor of the pit, front-end loaders push the refuse away from the tipping wall into either storage piles or to one of three reclaim pits located in the receiving floor. In each reclaim pit an apron feeder carries the refuse to an inclined apron conveyor, which transports the material to the primary shredder in the primary bulk separation section. The front-end loaders also sort any oversize bulky items that might be illegally dumped with the refuse and periodically remove them from the pit.

The receiving pit is enclosed by an unheated building 175 feet wide and 340 feet long. The receiving pit floor is 15 feet below the level of the tipping floor. Access to the pit is provided by a ramp opposite the tipping floor. High-intensity lighting is provided where necessary and closed-circuit television is used to monitor the entire operation.

Primary Bulk Separation

The primary bulk separation section removes the bulk of the refuse as RDF and separates the remaining material into several metal and mineral fractions. The section has been designed with three parallel processing lines. Two are needed to provide the necessary capacity and the third acts as a standby in case one line goes down. It is anticipated that the primary shredder will be damaged several times per week by large or very hard objects requiring 4 or more hours for repair. Each line has been designed on the basis of a

35-ton-per-hour flow, 7 hours per shift, with an extra 25 percent surge capacity, or a total of 44 tons per hour.[3] In this section two stages of shredding are used to liberate the various materials in the refuse, with most of the combustible fractions being recovered by air classification. Collection of magnetic and glass-rich fractions is accomplished by a magnetic separation step and a screening operation.

Raw refuse is fed directly from the receiving pit to the primary shredder which is a double-opposed flail mill. The refuse is coarsely shredded thereby liberating materials to be reclaimed but only denting or slicing cans (7). The shredder discharge conveyor is covered by a hood, referred to as the light-air classifier, which controls dusting and removes light refuse from the top of the moving bed. Airflow through the hood is caused by a suction fan pulling through a cyclone and a baghouse dust collector. Solids entrained in the airstream are collected in the cyclone.

Both the primary shredder and the light-air classifier are isolated from the rest of the process equipment by reinforced concrete walls. This protects the plant from danger in the event of an accidental explosion in the primary shredder. Operation of the equipment is monitored by closed-circuit television.

The shredded refuse is then conveyed to a magnetic belt separator suspended over the end of the conveyor. As the refuse is discharged onto another conveyor, most of the iron is removed by this device. Iron scrap, collected in this manner, is conveyed to the ferrous metal cleaning section.

The remaining nonmagnetic material is fed to a horizontal air classifier entering at one end of the classifier and falling into a stream of air injected by a blower. Massive materials fall straight through the airstream onto a conveyor. A magnetic head pulley separates these materials into magnetic and nonmagnetic fractions, which are conveyed to product collection bins. Other, less massive materials are blown past a divider where a suction fan, operating through a cyclone and a baghouse dust collector, induces a draft up through an opening in the bottom of the classifier and entrains light materials, which are collected by the cyclone. Materials blown past the divider but not entrained fall through the opening and are conveyed to a trommel-type screen.

Material sent to the trommel contains most of the glass, ceramics, dirt, nonferrous metals, food wastes, yard wastes, and other heavy combustibles. The glass, food wastes, ceramics, dirt, yard wastes, and small amounts of other material pass through the screen and are conveyed to the glass recovery section. The remaining material is conveyed to the secondary shredder, a knife-type hammermill, and reduced to minus 2-inch size. The shredder discharges directly into a three-stage aspirator. Suction applied to the aspirator through a cyclone and a baghouse dust collector draws air through the shredder, the bottom of the aspirator, and the side of the aspirator. The airstream entrains the light combustible material while a heavier, aluminum-rich fraction falls completely through and is conveyed to the nonferrous metal recovery section. The entrained solids are collected in the cyclone.

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[3] This excess capacity allows for variation in the feed composition, minor maintenance, and cleanup.

Glass Recovery

The glass recovery section uses a combined jigging and froth flotation operation to recover most of the glass in the refuse as clean cullet. This section and the remaining sections are designed using one process line operating 8 hours per shift and sufficient surge capacity is provided to insure a constant feed to the sections where needed. Material processed in this section comprises about 25 percent of the raw refuse fed to the plant, or about 16 tons per hour.

Minus 3/4-inch material from the trommel in the primary bulk separation section is conveyed to 5 surge bins, then fed from the bins to 10, 2 feet by 3 feet duplex mineral jigs. The jigs separate their feed into four fractions. Organics and putrescibles overflow the jig. Sands and fine glass filter through the screen and are collected as a hutch product. Small nonferrous metal, glass, and ceramics build up on the screen with the metals forming a separate layer directly on the screen. When the metal on the screen builds up sufficiently, it is removed through a port in the screen. The coarse glass and ceramics remaining on the screen constitute the main bed in the jig and are discharged continuously as a cup product.

Organics and water overflowing the jig, containing about 10 percent solids, are dewatered on a vibrating screen to about 20 percent solids. Water from the dewatering screen is recycled to the jig. The solids are then fed to a screw press, which removes enough water to give a 50-percent solid product. Water from the screw press is pumped to the water recovery section. The dewatered solids are then mixed with dust from the fuel recovery section and conveyed to a product collection bin.

The cup and hutch products are dewatered on a 20-mesh vibrating screen. The water and minus 20-mesh sands are pumped to the water recovery section. Plus 20-mesh glass and ceramics are fed to a two-stage grinding circuit consisting of a roll crusher and a rod mill. The roll crusher is set at 6 mesh, crushing the glass and ceramics but only flattening any tramp metal.

Crushed glass and ceramics are discharged from the roll crusher to a two-deck screen consisting of 1/4-inch and 20-mesh screens. Flattened tramp metal is collected on the 1/4-inch screen. The plus 20-mesh, minus 1/4-inch fraction is fed to a rod mill operating in closed circuit with a 20-mesh screen. The minus 20-mesh discharge from the rod mill screen is combined with the minus 20-mesh fraction from the two-deck screen. Product from the grinding circuit contains about 70 percent solids.

Minus 20-mesh glass and ceramics from the grinding circuit are mixed with water to produce a slurry containing about 25 percent solids. This slurry is pumped to a high-intensity wet magnetic separator where contaminating magnetic particles are removed. Slimes and minus 150-mesh material in the nonmagnetic slurry are then removed in a spiral classifier and pumped to the water recovery section.

The plus 150-mesh sand product from the classifier contains about 80 percent solids. This material is mixed with water to produce a 35-percent solid slurry. One-quarter pound each of a coco amine acetate flotation reagent and soda ash are added for each ton of solids in the slurry. The slurry is then fed to a bank of six flotation cells, consisting of four rougher cells and two cleaner cells. The flotation process selectively floats the glass portion of the feed, which is recovered as a froth containing about 55 percent solids. Tailings from the flotation cells are pumped to the water recovery section. The glass cullet is filtered on a horizontal belt filter, dried in a rotary dryer, then pneumatically conveyed to a product collection bin.

Ferrous Metal Cleaning

The ferrous metal fraction from the primary bulk separation section is fed to a horizontal air classifier similar to the units described in the primary bulk separation section. Ten percent of the feed to this unit is collected as massive metal and conveyed to the massive ferrous metal collection bin. Another 2.4 percent is entrained in the airstream and collected in a cyclone. The remaining material is fed to a tin can shredder and reduced in size to minus 2 inches.

After shredding, the ferrous metal is fed to a drum-type magnetic separator where food particles, paper, and other nonmagnetics are removed by water sprays. Wash water and nonmagnetic material fall on a vibrating screen. Solids collected on the screen are conveyed to landfill storage while the underflow is pumped to the water recovery section. The cleaned ferrous product is discharged from the drum magnet and conveyed to a collection bin.

RDF Handling

Combustibles, collected in the three cyclones in the primary bulk separation section and the cyclone in the ferrous metal recovery section, are discharged through rotary airlocks onto belt conveyors. The combustibles are combined with the heavy combustibles from the nonferrous recovery section and conveyed to a 30-foot-high storage bin. Combustibles (RDF) in the storage bin are compressed by the weight of the material above them. The bin discharges directly into four compactors, which load the RDF into unit containers for shipment by railroad or into transfer trailers for shipment by truck. The final density of the compacted product is about 20 pounds per cubic foot.

Dust, contained in the airstream for the cyclones, is collected in baghouses and mixed with the dewatered organics from the mineral jigs. This wet product, heavy organic fuel, is not compacted but loaded directly into separate containers for shipment.

Nonferrous Metal Recovery

The heavy material from the three-stage aspirator in the primary bulk separation section is fed to a nonferrous metal separator. This unit consists of multiple inclined stacks of a newly developed proprietary device that utilizes permanent magnets to generate eddy currents in the metals as they slide down the incline causing them to be deflected away from the nonmetallics (5). In this manner a rough separation is made. The feed is separated by this unit into three fractions: a 95-percent metal product, a 40-percent metal concentrate, and a heavy combustible fraction containing less than 4 percent metal.

The 40-percent metal concentrate is then dried in a moving belt dryer and fed to a high-tension separator. This unit recovers a 95-percent metal product, which is combined with the 95-percent metal product from the nonferrous metal separator and conveyed to a storage bin. The nonmetallic product from the unit is combined with the heavy combustibles from the nonferrous metal separator and conveyed to the RDF handling section.

Of the metal fed to the nonferrous metal separator, about 70 percent is recovered as the combined 95-percent metal product which is mostly shredded aluminum cans.

Water Recovery

Water requirements for this process are minimized by recycling the waste water. All the items of equipment which require water can use recycled water except for the froth flotation unit and the following filter which require pure water to maintain the purity of the glass cullet. Impurity buildup in the recycled water is limited by discarding to a sewer the water from the screw press in the glass recovery section after the water has been filtered to remove suspended solids.

Waste water streams from the glass recovery and ferrous metal recovery sections are pumped to a thickener. Overflow from the thickener is filtered to remove suspended solids and is then recycled. Thickener underflow is pumped to a rotary vacuum filter and dewatered. The filtrate is recycled to the thickener. Filter cakes from the two filters are conveyed to a landfill collection bin.

ECONOMICS

The cost estimate presented in the report is based on data from the Bureau of Mines pilot plant in Edmonston, Md. Cost data used are from quotations obtained from equipment manufacturers or from published sources brought up to date by the use of inflation indexes.

Capital Costs

The capital cost estimate is of the type called "study estimate" by Weaver and Bauman (8) and is expected to be within 30 percent of the actual cost. The fixed capital cost is on a second quarter 1976 basis, and is summarized in table 2.

TABLE 2. - Estimated capital cost[1]

Fixed capital:	
Refuse receiving	$2,576,400
Primary bulk separation	4,251,300
Glass recovery	2,101,400
Ferrous metal cleaning	489,800
RDF handling	1,046,800
Nonferrous metal recovery	934,500
Water recovery	502,700
Subtotal	11,902,900
Plant facilities, 10 percent of above subtotal	1,190,300
Plant utilities, 5 percent of above subtotal	595,100
Total plant cost	13,688,300
Interest during construction period	841,300
Fixed capital cost	14,529,600
Working capital:	
Raw material and supplies	8,200
Accounts receivable	201,000
Available cash	102,500
Working capital cost	311,700
Total capital cost	14,841,300

[1]Basis: M and S (Marshale and Swift) equipment cost index = 468.5.

NOTE.--Land and RDF shipping container costs are not included.

Costs for most of the major items of equipment are based on quotations by equipment manufacturers contacted during preparation of this evaluation. For other items of equipment, cost-capacity data of the type shown by Bauman (1) and Mills (2) are used. Equipment costs and accessories are tabulated for each section in the appendix at the end of this report. Factors for piping, instruments, and the like are assigned to each section, depending on whether fluids, solids, or a combination of fluids and solids are handled. These factors are shown for each section in the appendix. A factor of 10 percent, referred to as miscellaneous, is added to each section to cover minor equipment and construction costs that are not shown with the equipment listed for the section.

For each section the field indirect cost, which covers field supervision, inspection, temporary construction, equipment rental, and payroll overhead, is estimated as 10 percent of the direct cost. Engineering and administration and overhead are each estimated as 5 percent of the construction cost. A contingency of 10 percent and a contractor's fee of 5 percent are included in the section costs.

The costs of plant facilities and utilities are estimated as 10 and 5 percent, respectively, of the total process section costs. The costs of plant facilities and utilities include the same field indirect cost, engineering, administration and overhead, contingency, and contractor's fee that are included in the section costs. Included under plant facilities are the costs of laboratories, shops, roads, railroad sidings, and fences. The costs of water and power distribution systems are included under plant utilities.

The cost for interest on the capital borrowed for construction is included as interest during the construction period, assuming an 8-percent interest rate over an 18-month construction period with progress payments based on the degree of completion.

Working capital is defined as the funds in addition to fixed capital, land investment, and startup costs that must be provided to operate the plant. Working capital, also shown in table 2, is estimated from the following items: (1) Raw material and supplies inventory (cost of raw material and operating supplies for 1 month), (2) accounts receivable (total operation cost for 1 month), and (3) available cash (direct expenses for 1 month).

Land investment and startup costs are not included in this estimate.

Operating Costs

The estimated operating costs are based on the plant operating 6 days per week, 52 weeks per year. The plant is expected to operate an average of 304 days per year over the life of the plant, which allows the plant to be closed 8 days per year for holidays. Operation is scheduled on the first and second shift, and inspection and maintenance are performed on the third shift. No time has been allowed for unscheduled interruptions; however, a third processing line has been included for standby use. The operating costs are divided into direct, indirect, and fixed costs.

Direct costs include raw materials, utilities, direct labor, plant maintenance, payroll overhead, and operating supplies. The raw material costs do not include transportation costs because the plant location is not considered. No tipping charge for the refuse, dumping charge for the landfill generated, nor value for the products are assigned so that only the operating expenses are determined. Raw material and utility requirements per ton of refuse are shown in the appendix.

The direct labor cost is estimated on the basis of manning the plant with 2.4 men for each position that operates 16 hours per day, 6 days per week. The direct labor assignments are shown by section in table A-3. The cost of labor supervision is estimated as 15 percent of the labor costs. The labor rate used is a composite rate based on the Federal Government pay schedule for laborers and operators. This is to approximate a municipal pay schedule.

Plant maintenance is separately estimated for each piece of equipment and for the buildings, electrical system, piping, plant utility distribution systems, and plant facilities.

Payroll overhead, estimated as 25 percent of direct labor and maintenance labor, includes vacation, sick leave, social security, and fringe benefits. The cost of operating supplies is estimated as 20 percent of the cost of plant maintenance.

Indirect costs are estimated as 40 percent of the direct labor and maintenance costs. The indirect costs include the expenses of control laboratories, accounting, plant protection and safety, plant administration, marketing, and company overhead. Research and overall company administrative costs outside the plant are not included.

Fixed costs include the cost of insurance and depreciation. The plant is assumed to be owned by a city or State government; therefore, no local taxes are included. The annual cost of insurance is estimated as 1 percent of the plant construction costs. Depreciation is based on a straight-line, 20-year period.

The estimated annual operating costs for a plant processing 1,000 tons per day of raw urban refuse with no product credits and no tipping, finance, or landfill disposal charges is approximately $2.4 million, or approximately $8 per ton of refuse processed (table 3).

The operating cost listed in table 3 does not include a landfill disposal charge as this will vary from one location to the next.

Products

The products recovered from the raw refuse are light-gage iron, massive iron, aluminum scrap, mixed heavy nonferrous scrap, massive nonferrous metals, a mixed-color glass cullet, a heavy organic fuel, and RDF. In addition, about 56 tons of landfill will be produced from 1,000 tons of refuse. The RDF is compacted into unit containers or into transfer trailers for shipment by rail or truck. All other products are collected in bins then loaded directly into trucks or railroad cars for shipment. It is assumed that the products will be shipped immediately as no onsite storage of the products has been provided except to provide surge capacity to facilitate loading for shipment.

The estimated value of the products from the separation process is $12.60 per ton of refuse processed, assuming the products are delivered to the customer's plant, and is listed in table 4. Fuel values are estimated as 75 percent of the value of an equivalent amount of coal based on energy content. Although the value of coal varies depending on location, an average value of $23 per ton has been used for a coal with an energy content of 12,500 Btu's per pound. Based on typical experimental data, the energy content of the RDF product is assumed to be 6,500 Btu's per pound and the value used for the heavy organic fuel product is 4,000 Btu's per pound. The product values for the metal and glass products were determined based on communications with industrial sources. Markets for shredded aluminum and tin can scrap (light-gage iron) are already established and these product values are expected to be reasonably accurate. The remaining product values are not as well defined, but the sources have indicated that prospective markets do exist although the product value may vary depending on the individual market.

TABLE 3. - Estimated annual operating cost

	Annual cost	Cost per ton of raw refuse
Direct cost:		
Raw materials:		
Soda ash at $0.04 per pound	$300	$0.01
Coco amine acetate at $0.88 per pound	5,900	.02
Replacement rods for grinding at $0.11 per pound	2,600	.01
Total	8,800	.04
Utilities:		
Electric power at $0.017 per kwhr	99,400	.33
Water, process at $0.50 per Mgal	9,900	.03
Fuel oil at $2 per MMBtu	72,900	.24
Total	182,200	.60
Direct labor:		
Labor at $5 per hour	301,600	.99
Supervision, 15 percent of labor	45,200	.15
Total	346,800	1.14
Plant maintenance:		
Labor	224,300	.74
Supervision, 20 percent of maintenance labor	44,900	.15
Materials	179,500	.59
Total	448,700	1.48
Payroll overhead, 25 percent of above payroll	154,000	.51
Operating supplies, 20 percent of plant maintenance	89,700	.30
Total direct cost	1,230,200	4.07
Indirect cost, 40 percent of direct labor and maintenance	318,200	1.05
Fixed cost:		
Insurance, 1.0 percent of total plant cost	136,900	.45
Depreciation, 20-year life	726,500	2.39
Total operating cost	2,411,800	7.96

TABLE 4. - Estimated product values delivered to customer's plant

Product	Per ton of product	Per ton of refuse
Refuse-derived fuel (RDF)	$8.97	$5.99
Heavy organic fuel	5.52	.77
Light-gage iron	39	2.18
Mixed-color glass cullet	21	1.60
Nonferrous metal (aluminum)	300	1.32
Mixed heavy nonferrous metals	160	.16
Massive iron	20	.22
Massive nonferrous metals	120	.36
Total	-	12.60

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APPENDIX.--THERMAL AND UTILITY REQUIREMENTS, AND EQUIPMENT COST SUMMARIES

Raw material and utility requirements per ton of raw refuse are shown in table A-1 and the major items of equipment for each section are shown in table A-2. The direct labor requirements for each section are shown in table A-3. The daily utility and thermal requirements are given in tables A-4 and A-5, respectively. The equipment costs for each section of the process are contained in tables A-6 to A-12.

TABLE A-1.-RAW MATERIAL AND UTILITY REQUIREMENTS

	QUANTITY PER TON RAW REFUSE
RAW MATERIALS:	
SODA ASH, POUND........................	.022
COCO AMINE ACETATE, POUND.............	.022
REPLACEMENT RODS FOR GRINDING, POUND..	.075
UTILITIES:	
ELECTRIC POWER, KWHR..................	19.242
PROCESS WATER, MGAL...................	.065
FUEL OIL, MMBTU.......................	.120

TABLE A-2. - MAJOR ITEMS OF EQUIPMENT

SECTION AND ITEM	QUANTITY	UNIT SIZE
PRIMARY BULK SEPARATION		
FLAIL MILLS	3	50 TONS PER HOUR.
TROMMELS	3	8 FEET IN DIAMETER BY 24 FEET LONG.
SECONDARY SHREDDERS	3	17 TONS PER HOUR.
CYCLONES	3	12 FEET IN DIAMETER.
CYCLONES	3	13.7 FEET IN DIAMETER.
CYCLONES	3	9 FEET IN DIAMETER.
GLASS RECOVERY		
MINERAL JIGS	10	24 INCH BY 36 INCH DUPLEX.
ROLL CRUSHER	1	20 INCH DIAMETER ROLLS.
RODMILL	1	3 FEET IN DIAMETER BY 8 FEET.
MAGNETIC SEPARATOR	1	10 TONS PER HOUR.
DESLIMEING CLASSIFIER	1	24 INCH SINGLE PITCH.
FLOTATION CELLS	1	6 CELLS, 18 BY 18 INCHES.
VACUUM BELT FILTER	1	2 FEET BY 3 FEET.
ROTARY DRYER	1	3.75 FEET IN DIAMETER BY 30 FEET.
FERROUS METAL CLEANING		
TIN CAN SHREDDER	1	8 TONS PER HOUR.
CYCLONE	1	8 FEET IN DIAMETER.
RDF HANDLING		
COMPACTORS	4	976 CUBIC YARDS PER HOUR.
NONFERROUS METAL RECOVERY		
NONFERROUS METAL SEPARATOR	1	30 FEET BY 15 FEET BY 25 FEET.
DRYER	1	10 FEET BY 82 FEET.
HIGH TENSION SEPARATOR	1	TWO 60 INCH ROTORS.
WATER RECOVERY		
THICKENER	1	44 FEET IN DIAMETER.

TABLE A-3. - DIRECT LABOR REQUIREMENTS, MEN PER SHIFT

SECTION	SHIFTS PER DAY 2
REFUSE RECEIVING	4
PRIMARY BULK SEPARATION	2
GLASS PROCESSING	2
RDF HANDLING	3
NONFERROUS METAL RECOVERY	1
TOTAL	12

TABLE A-4. - DAILY UTILITY REQUIREMENTS

SECTION AND ITEM	ELECTRIC POWER, KWHR	PROCESS WATER, MGAL
REFUSE RECEIVING:		
SUBTOTAL	419.	0.
PRIMARY BULK SEPARATION:		
SUBTOTAL	10556.	0.
GLASS RECOVERY:		
MIXING TANK	-	34.
MIXING TANK	-	24.
VACUUM BELT FILTER	-	7.
SUBTOTAL	3332.	65.
FERROUS METAL CLEANING:		
SUBTOTAL	3057.	0.
RDF HANDLING:		
SUBTOTAL	927.	0.
NONFERROUS METAL RECOVER:		
SUBTOTAL	514.	0.
WATER RECOVERY:		
SUBTOTAL	437.	0.
TOTAL	19242.	65.

TABLE A-5. - DAILY THERMAL REQUIREMENTS

SECTION AND ITEM	FUEL OIL, MMBTU
GLASS RECOVERY: ROTARY DRYER........	33.9
NONFERROUS METAL RECOVERY: DRYER....	11.0
GENERAL PLANT.......................	75.0
TOTAL...........................	119.9

TABLE A-6.-EQUIPMENT COST SUMMARY, REFUSE RECEIVING

ITEM	COST(1) EQUIPMENT	COST(1) LABOR	COST(1) TOTAL
TRUCK SCALES......................	$ 73400	$ 14200	$ 87600
APRON FEEDERS.....................	105500	20800	126300
APRON CONVEYORS...................	194900	38500	233400
TOTAL..........................	373800	73500	447300
WEIGH SCALE BUILDING..................................			(2) 5000
TIPPING BUILDING......................................			(2) 975100
FRONT-END LOADERS.....................................			147300
TOTAL EQUIPMENT COST X FACTOR INDICATED:			
FOUNDATIONS, X .158................................			59200
STRUCTURES, X .220.................................			82200
INSTRUMENTATION, X .120............................			44800
ELECTRICAL, X .061.................................			22800
PAINTING, X .060...................................			22400
MISCELLANEOUS, X .100..............................			37400
TOTAL..			268800
TOTAL DIRECT COST..................................			1843500
FIELD INDIRECT, 10.0 PERCENT OF TOTAL DIRECT COST......			184300
TOTAL CONSTRUCTION COST............................			2027800
ENGINEERING, 5.0 PERCENT OF TOTAL CONSTRUCTION COST...			101400
ADMINISTRATION AND OVERHEAD, 5.0 PERCENT OF TOTAL CONSTRUCTION COST..................................			101400
SUBTOTAL...			2230600
CONTINGENCY, 10.0 PERCENT OF ABOVE SUBTOTAL...........			223100
SUBTOTAL...			2453700
CONTRACTOR'S FEE, 5.0 PERCENT OF ABOVE SUBTOTAL.......			122700
SECTION COST.......................................			2576400

(1) EQUIPMENT COSTS ARE BASED ON THE M AND S INDEX OF 468.5.
(2) INSTALLED COST.

TABLE A-7.-EQUIPMENT COST SUMMARY, PRIMARY BULK SEPARATION

ITEM	COST(1)		
	EQUIPMENT	LABOR	TOTAL
FLAIL MILLS	$ 126500	$ 2500	$ 129000
BELT CONVEYORS	21000	4500	25500
BELT CONVEYORS	21000	4500	25500
LIGHT AIR CLASSIFIERS	6000	800	6800
MAGNETIC BELT SEPARATORS	57000	500	57500
BELT CONVEYOR	14800	3300	18100
BELT CONVEYOR	8100	1900	10000
BELT CONVEYORS	32900	7400	40300
HORIZONTAL AIR CLASSIFIERS	13500	600	14100
BLOWERS	10000	1300	11300
BELT CONVEYOR	20700	3800	24500
BELT CONVEYOR	13000	2800	15800
STORAGE BIN	200	100	300
BELT CONVEYORS	22000	4900	26900
TROMMELS	77600	9500	87100
BELT CONVEYOR	12600	2900	15500
BELT CONVEYOR	9800	2200	12000
BELT CONVEYOR	17200	1900	19100
BELT CONVEYORS	21800	4900	26700
SECONDARY SHREDDERS	270000	2500	272500
THREE STAGE ASPIRATORS	22100	500	22600
BELT CONVEYOR	8800	2200	11000
CYCLONES	113100	900	114000
BAG DUST COLLECTORS	71400	800	72200
CYCLONES	126200	1100	127300
BAG DUST COLLECTORS	86500	900	87400
CYCLONES	95500	800	96300
BAG DUST COLLECTORS	42200	700	42900
TOTAL	1341500	70700	1412200
TOTAL EQUIPMENT COST X FACTOR INDICATED:			
FOUNDATIONS, X .119			159800
BUILDINGS, X .553			741300
STRUCTURES, X .100			134100
INSTRUMENTATION, X .044			59700
ELECTRICAL, X .152			204100
PIPING, X .100			134100
PAINTING, X .047			62600
MISCELLANEOUS, X .100			134100
TOTAL			1629800
TOTAL DIRECT COST			3042000
FIELD INDIRECT, 10.0 PERCENT OF TOTAL DIRECT COST			304200
TOTAL CONSTRUCTION COST			3346200
ENGINEERING, 5.0 PERCENT OF TOTAL CONSTRUCTION COST			167300
ADMINISTRATION AND OVERHEAD, 5.0 PERCENT OF TOTAL CONSTRUCTION COST			167300
SUBTOTAL			3680800
CONTINGENCY, 10.0 PERCENT OF ABOVE SUBTOTAL			368100
SUBTOTAL			4048900
CONTRACTOR'S FEE, 5.0 PERCENT OF ABOVE SUBTOTAL			202400
SECTION COST			4251300

(1) EQUIPMENT COSTS ARE BASED ON THE M AND S INDEX OF 468.5.

TABLE A-8.-EQUIPMENT COST SUMMARY, GLASS RECOVERY

ITEM	COST(1)		
	EQUIPMENT	LABOR	TOTAL
SURGE BINS	$ 5700	$ 2200	$ 7900
VIBRATING FEEDERS	3700	600	4300
MINERAL JIGS	132000	2100	134100
DEWATERING SCREENS	15200	2400	17600
SUMP	2000	100	2100
PUMP	2100	700	2800
BELT CONVEYOR	7800	1600	9400
DEWATERING PRESS	52700	200	52900
SCREW FEEDER	8400	500	8900
SUMP	1700	100	1800
PUMP	2000	600	2600
BELT CONVEYOR	11100	2500	13600
VIBRATING SCREENS	13100	2100	15200
SUMP	4200	200	4400
PUMPS	3600	1100	4700
BELT CONVEYOR	6000	1400	7400
BELT CONVEYOR	3200	600	3800
BUCKET ELEVATOR	3500	700	4200
HOPPER	500	100	600
VIBRATING FEEDER	600	100	700
ROLL CRUSHER	12000	500	12500
VIBRATING SCREEN	4500	700	5200
BELT CONVEYOR	5100	900	6000
VIBRATING FEEDER	700	100	800
RODMILL	16800	1300	18100
VIBRATING SCREEN	4200	700	4900
BELT CONVEYOR	5200	1100	6300
MIXING TANK	5300	300	5600
PUMPS	4200	1300	5500
MAGNETIC SEPARATOR	68100	1100	69200
DESLIMEING CLASSIFIER	8500	900	9400
SUMP	2600	100	2700
PUMPS	5300	1500	6800
MIXING TANK	4800	200	5000
REAGENT FEEDERS	1900	300	2200
PUMP	1800	600	2400
FLOTATION CELLS	12500	500	13000
MIXING TANK	4700	200	4900
PUMP	1700	500	2200
VACUUM BELT FILTER	16200	1700	17900
BELT CONVEYOR	5000	1100	6100
HOPPER	600	100	700
VIBRATING FEEDER	700	100	800
ROTARY DRYER	59200	9500	68700
CYCLONE DUST COLLECTOR	2300	100	2400
PNEUMATIC CONVEYOR	9800	5300	15100
GLASS STORAGE BIN	700	200	900
LANDFILL COLLECTION BIN	400	100	500
TOTAL	543900	50900	594800
METAL COLLECTION BIN			(2) 300
TRAMP METAL COLLECTION BIN			(2) . 300

TABLE A-8.-EQUIPMENT COST SUMMARY, GLASS RECOVERY--Continued

TOTAL EQUIPMENT COST X FACTOR INDICATED:	
FOUNDATIONS, X .248	135000
STRUCTURES, X .100	54400
INSTRUMENTATION, X .232	126300
ELECTRICAL, X .350	190400
PIPING, X .600	326300
PAINTING, X .039	21400
MISCELLANEOUS, X .100	54400
TOTAL	908200
TOTAL DIRECT COST	1503600
FIELD INDIRECT, 10.0 PERCENT OF TOTAL DIRECT COST	150400
TOTAL CONSTRUCTION COST	1654000
ENGINEERING, 5.0 PERCENT OF TOTAL CONSTRUCTION COST	82700
ADMINISTRATION AND OVERHEAD, 5.0 PERCENT OF TOTAL CONSTRUCTION COST	82700
SUBTOTAL	1819400
CONTINGENCY, 10.0 PERCENT OF ABOVE SUBTOTAL	181900
SUBTOTAL	2001300
CONTRACTOR'S FEE, 5.0 PERCENT OF ABOVE SUBTOTAL	100100
SECTION COST	2101400

(1) EQUIPMENT COSTS ARE BASED ON THE M AND S INDEX OF 468.5.
(2) INSTALLED COST.

TABLE A-9.-EQUIPMENT COST SUMMARY, FERROUS METAL CLEANING

ITEM	COST(1)		
	EQUIPMENT	LABOR	TOTAL
VIBRATING FEEDER	$ 700	$ 100	$ 800
HORIZONTAL AIR CLASSIFIER	700	200	900
BLOWER	900	100	1000
BELT CONVEYOR	4800	600	5400
BELT CONVEYOR	4700	1000	5700
BELT CONVEYOR	13100	2900	16000
BELT CONVEYOR	3800	700	4500
BUCKET ELEVATOR	4200	800	5000
TIN CAN SHREDDER	42000	700	42700
BELT CONVEYOR	3600	700	4300
BELT CONVEYOR	3800	800	4600
MAGNETIC SEPARATOR	14800	500	15300
VIBRATING SCREEN	2200	300	2500
BELT CONVEYOR	12600	3400	16000
SUMP	1300	100	1400
PUMP	1700	200	1900
BELT CONVEYOR	9300	2000	11300
STORAGE BIN	1800	900	2700
CYCLONE	28100	200	28300
BAG DUST COLLECTOR	11400	200	11600
TOTAL	165500	16400	181900
TOTAL EQUIPMENT COST X FACTOR INDICATED:			
FOUNDATIONS, X .193			31900
STRUCTURES, X .100			16500
INSTRUMENTATION, X .056			9300
ELECTRICAL, X .303			50200
PIPING, X .200			33100
PAINTING, X .067			11100
MISCELLANEOUS, X .100			16500
TOTAL			168600
TOTAL DIRECT COST			350500
FIELD INDIRECT, 10.0 PERCENT OF TOTAL DIRECT COST			35000
TOTAL CONSTRUCTION COST			385500
ENGINEERING, 5.0 PERCENT OF TOTAL CONSTRUCTION COST			19300
ADMINISTRATION AND OVERHEAD, 5.0 PERCENT OF TOTAL CONSTRUCTION COST			19300
SUBTOTAL			424100
CONTINGENCY, 10.0 PERCENT OF ABOVE SUBTOTAL			42400
SUBTOTAL			466500
CONTRACTOR'S FEE, 5.0 PERCENT OF ABOVE SUBTOTAL			23300
SECTION COST			489800

(1) EQUIPMENT COSTS ARE BASED ON THE M AND S INDEX OF 468.5.

TABLE A-10.-EQUIPMENT COST SUMMARY, RDF HANDLING

ITEM	COST(1)		
	EQUIPMENT	LABOR	TOTAL
BELT CONVEYOR	$ 37000	$ 8500	$ 45500
BELT CONVEYOR	9000	2000	11000
BELT CONVEYOR	31200	7200	38400
BELT CONVEYOR	34800	7000	41800
SCREW FEEDER	22000	4300	26300
COMPACTORS	112000	14800	126800
TOTAL	246000	43800	289800
RDF STORAGE BIN			(2) 193500
FORKLIFT TRUCKS			27100
TOTAL EQUIPMENT COST X FACTOR INDICATED:			
FOUNDATIONS, X .194			47700
STRUCTURES, X .258			63400
INSTRUMENTATION, X .020			4900
ELECTRICAL, X .144			35500
PIPING, X .200			49200
PAINTING, X .055			13400
MISCELLANEOUS, X .100			24600
TOTAL			238700
TOTAL DIRECT COST			749100
FIELD INDIRECT, 10.0 PERCENT OF TOTAL DIRECT COST			74900
TOTAL CONSTRUCTION COST			824000
ENGINEERING, 5.0 PERCENT OF TOTAL CONSTRUCTION COST			41200
ADMINISTRATION AND OVERHEAD, 5.0 PERCENT OF TOTAL CONSTRUCTION COST			41200
SUBTOTAL			906400
CONTINGENCY, 10.0 PERCENT OF ABOVE SUBTOTAL			90600
SUBTOTAL			997000
CONTRACTOR'S FEE, 5.0 PERCENT OF ABOVE SUBTOTAL			49800
SECTION COST			1046800

(1) EQUIPMENT COSTS ARE BASED ON THE M AND S INDEX OF 468.5.
(2) INSTALLED COST.

TABLE A-11.-EQUIPMENT COST SUMMARY, NONFERROUS METAL RECOVERY

ITEM	COST(1)		
	EQUIPMENT	LABOR	TOTAL
BELT CONVEYOR	$ 4000	$ 900	$ 4900
BUCKET ELEVATOR	3700	700	4400
SURGE BIN	1600	700	2300
VIBRATING FEEDER	700	100	800
NONFERROUS METAL SEPARATOR	147700	16200	163900
BELT CONVEYOR	10900	2900	13800
BELT CONVEYOR	12000	2800	14800
BELT CONVEYOR	3700	800	4500
HOPPER	100	100	200
VIBRATING FEEDER	700	100	800
DRYER	154800	14200	169000
BELT CONVEYOR	4200	900	5100
BUCKET ELEVATOR	3000	600	3600
HOPPER	100	100	200
VIBRATING FEEDER	700	100	800
HIGH TENSION SEPARATOR	41100	2100	43200
BELT CONVEYOR	3000	600	3600
BELT CONVEYOR	8500	2100	10600
TOTAL	400500	46000	446500
TOTAL EQUIPMENT COST X FACTOR INDICATED:			
FOUNDATIONS, X .135			54000
STRUCTURES, X .100			40000
INSTRUMENTATION, X .005			2000
ELECTRICAL, X .095			38000
PIPING, X .100			40000
PAINTING, X .020			8100
MISCELLANEOUS, X .100			40000
TOTAL			222100
TOTAL DIRECT COST			668600
FIELD INDIRECT, 10.0 PERCENT OF TOTAL DIRECT COST			66900
TOTAL CONSTRUCTION COST			735500
ENGINEERING, 5.0 PERCENT OF TOTAL CONSTRUCTION COST			36800
ADMINISTRATION AND OVERHEAD, 5.0 PERCENT OF TOTAL CONSTRUCTION COST			36800
SUBTOTAL			809100
CONTINGENCY, 10.0 PERCENT OF ABOVE SUBTOTAL			80900
SUBTOTAL			890000
CONTRACTOR'S FEE, 5.0 PERCENT OF ABOVE SUBTOTAL			44500
SECTION COST			934500

(1) EQUIPMENT COSTS ARE BASED ON THE M AND S INDEX OF 468.5.

TABLE A-12.-EQUIPMENT COST SUMMARY, WATER RECOVERY

ITEM	COST(1)		
	EQUIPMENT	LABOR	TOTAL
THICKENER	$ 24800	$ 2700	$ 27500
PUMP	1200	1000	2200
PRESSURE LEAF FILTER	39700	3100	42800
STORAGE TANK	5300	300	5600
PUMP	1000	1000	2000
PUMPS	3400	800	4200
VACUUM BELT FILTER	16200	1700	17900
STORAGE TANK	1500	100	1600
PUMP	500	300	800
BELT CONVEYOR	12400	3200	15600
BELT CONVEYOR	10400	2700	13100
BUCKET ELEVATOR	3900	800	4700
BELT CONVEYOR	6000	1300	7300
TOTAL	126300	19000	145300
TOTAL EQUIPMENT COST X FACTOR INDICATED:			
FOUNDATIONS, X .314			39600
BUILDINGS, X .098			12400
STRUCTURES, X .050			6300
INSTRUMENTATION, X .217			27400
ELECTRICAL, X .348			43900
PIPING, X .500			63200
PAINTING, X .072			9000
MISCELLANEOUS, X .100			12600
TOTAL			214400
TOTAL DIRECT COST			359700
FIELD INDIRECT, 10.0 PERCENT OF TOTAL DIRECT COST			36000
TOTAL CONSTRUCTION COST			395700
ENGINEERING, 5.0 PERCENT OF TOTAL CONSTRUCTION COST			19800
ADMINISTRATION AND OVERHEAD, 5.0 PERCENT OF TOTAL CONSTRUCTION COST			19800
SUBTOTAL			435300
CONTINGENCY, 10.0 PERCENT OF ABOVE SUBTOTAL			43500
SUBTOTAL			478800
CONTRACTOR'S FEE, 5.0 PERCENT OF ABOVE SUBTOTAL			23900
SECTION COST			502700

(1) EQUIPMENT COSTS ARE BASED ON THE M AND S INDEX OF 468.5.

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